

AU/ACSC/0070/97-03

**THE HEAVY BOMBER INDUSTRIAL BASE:
A STUDY OF PRESENT AND FUTURE CAPABILITIES**

A Research Paper

Presented To

The Research Department

Air Command and Staff College

In Partial Fulfillment of the Graduation Requirements of ACSC

by

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March 1997

| Report Documentation Page | | |
|---|---------------------------|--|
| Report Date 00031997 | Report Type N/A | Dates Covered (from... to) - - |
| Title and Subtitle The Heavy Bomber Industrial Base: A Study of Present and Future Capabilities | | Contract Number |
| | | Grant Number |
| | | Program Element Number |
| Author(s) Barefield, II, James L. | | Project Number |
| | | Task Number |
| | | Work Unit Number |
| Performing Organization Name(s) and Address(es) Air Command and Staff College Maxwell AFB, AL 36112 | | Performing Organization Report Number |
| Sponsoring/Monitoring Agency Name(s) and Address(es) | | Sponsor/Monitor's Acronym(s) |
| | | Sponsor/Monitor's Report Number(s) |
| Distribution/Availability Statement Approved for public release, distribution unlimited | | |
| Supplementary Notes The original document contains color images. | | |
| Abstract | | |
| Subject Terms | | |
| Report Classification unclassified | | Classification of this page unclassified |
| Classification of Abstract unclassified | | Limitation of Abstract UNLIMITED |
| Number of Pages 49 | | |

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Preface

To Congress, the end of the Cold War translates to the opportunity for a reduced military force structure. However, the United States continue to face a wide array of ever-changing security challenges. Regional conflicts or crises which jeopardize our nation's vital interests could erupt at any time and at any location. As the number of forward-deployed aircraft carriers decline and the U.S. gradually withdraws from its overseas installations, it will become increasingly difficult to use tactical aircraft in bombing missions. In addition, recent indications of severely reduced development and procurement budgets for military weapons systems have generated concern about the continuing viability of our country's defense aerospace industrial base.

One specific area of considerable concern for many years has been the proper bomber force structure and the industrial base supporting such strategic weapons systems. It seems as though each year our nation's political leaders debate over the proper number of bombers required to meet tomorrow's challenges. Some assert that the procurement of additional heavy bombers comes at the expense of other resources needed for future defense needs, thereby actually reducing the overall level of national security. Those individuals would believe that the supporting bomber industrial base is sufficiently robust. To the contrary, there are others in the military and civilian communities that believe the nation's present long-range bomber force, consisting of approximately 200 bombers after all B-2 deliveries, is not enough to meet future requirements, particularly in view of the

potential attrition that would occur in a conflict and the eventual need to retire the B-52s.

Since there is no further bomber acquisition presently planned, these individuals are concerned about the impact of inactivity should the need arise for production of additional long-range bombers. This concern is the catalyst behind this study.

This Air Command and Staff College research project analyzes the heavy bomber industrial base and the present and future health of this national infrastructure. In addition, actions to mitigate cost and schedule impacts to future bomber production have been included for consideration.

I sincerely appreciate the contributions of Mr. James Gifford, Mrs. Patty Boggs, and Mr. Bill Haslett, Northrop Grumman Military Aircraft Systems Division; Mr. Don Carson, The Analytical Sciences Corporation; Lieutenant Colonel (s) Ken Farrell, Air Force Program Executive Office for Fighters and Bombers, Pentagon; and Major Tony Williams, Air Command and Staff College Faculty Advisor. Their timely inputs, wise guidance, and contagious motivation encouraged me to create a research product I believe will be of significance and usefulness to the defense community.

Abstract

The declining procurement level and reduced quantity of new program starts driven by a dramatically smaller defense budget have generated concern for the continuing viability of the defense industrial base. Recent research on the impact of the aerospace industrial base's downsizing relative to heavy bomber production has narrowly focused on the loss of technical and theoretical capabilities. Researchers have adopted this position despite the fact the United States has repeatedly demonstrated its ingenuity and capacity to design and build weapons systems exploiting state-of-the-art technology. This research was conducted to demonstrate that merely assessing the loss of mental and physical capital will not provide America with a realistic assessment of its future ability to field a threatening heavy bomber force.

The thesis of this research is that the concern for heavy bomber production should not be limited to just maintaining the critical skills and capabilities necessary to produce these aircraft, but rather should increase in scope to examine the practical feasibility of procuring bombers in the future *at acceptable costs and within required timelines*. There are numerous reasons indicating that additional heavy bombers may be required at some point within the next ten years. If the present bomber production capability is allowed to drawdown without a comprehensive consideration for future defense needs, tomorrow's inevitable bomber production requirements will severely feel this oversight in terms of money and time. Immediate action to enhance the present B-2 curtailment program,

combined with the development of a government/industry industrial strategy comparing B-2 post-production support requirements and capabilities against potential bomber production restart needs, will significantly minimize future costs and schedule impacts if in fact future bomber production is required in the upcoming decade.

The following study focuses on the industrial base's current and future capability to design, develop, and produce heavy bomber aircraft. Chapter 1 reviews the nation's needs for heavy bombers, discusses three reasons which may determine the need for additional bombers in the future, examines the bomber industrial base in terms of the broader aerospace industry, and defines the B-2 bomber's present curtailment status and production activities. Chapter 2 assesses the role of experience in past aircraft production. Chapter 3 examines the industry's ability to reconstitute bomber production in the future by analyzing B-1 bomber restart activities and the lessons learned from this most recent heavy bomber experience. Chapter 4 reviews recent political, military, and industry activity aimed at maintaining the bomber industrial base and analyzes the Department of Defense's *Fiscal Year 1995 Heavy Bomber Industrial Base Capabilities Study*. Chapter 5 provides conclusions and suggestions to mitigate cost and schedule impacts to future bomber production.

This research draws primarily on historical resources in addition to accomplishing limited new analyses. Research sources included: relative professional studies, topic-oriented periodicals and books, prepared Congressional testimony, electronic media, letters and briefings, and personal interviews with and speeches by subject matter experts.

Chapter 1

Background and Study Overview

Not only must we maintain the bombers we have, we must preserve our capacity to produce bombers for the long term. We have invested heavily in technologies based on stealth and modern manufacturing techniques that are unique to bombers. Our bomber industrial base is a national asset—we must find a way to preserve it.

— General (ret) John M. Loh

The defense budget of the United States has declined substantially after reaching its pinnacle in the mid-1980s. Many experts, both military and civilian, project continuing budget decreases for the remainder of the 1990s and perhaps even into the 21st century. In September 1996, Dr. Paul Kaminski, The Under Secretary of Defense for Acquisition and Technology stated, “As I see it, the pressure on defense spending will continue. The real value of defense spending has declined in each of the last eleven years since 1986.”¹

Even with the dissolution of the former Soviet Union, the remaining increasingly uncertain threat environment around the world has generated far-reaching interest concerning the overall health of the U.S. defense industry that supports aerospace needs. Some experts believe that the inevitable contraction of the defense aerospace industry will result in problems in terms of the industry’s ability to respond to future national defense needs. Others think that “it could be in the national interest for the Department of

Defense (DOD) to take special measures to ensure the continued viability of certain sectors of the industry”² whose product lines target unique military applications.

Declining defense spending will inevitably drive some aerospace related companies out of the market. Some experts believe the results of this corporate downsizing will be a decreased defense-related production capacity and a less robust, less capable defense industry. However, this general contraction of the defense industrial base does not necessarily equate to unacceptable risks to U.S. national security interests. In remarks presented before the World Affairs Council of Philadelphia on September 29, 1993, Norman R. Augustine, then Chairman and Chief Executive Officer of Martin Marietta Corporation, stated that “the only justification for America’s defense industry is to meet the needs of national security. There can be no other self-sufficient reason.”³

However, shrinking of the defense aerospace industrial base can pose unacceptable risks to American national security interests if core manufacturing processes, technologies, production capabilities, and integration skills are sacrificed during the course of downsizing. Losing these critical capabilities could raise the risks both that, in a crisis, America would be unable to meet DOD’s material requirements and that, over the longer term, the U. S. would lose the capacity to develop and deliver advanced systems.

This research paper is an appraisal of such issues with respect to one product line: heavy bombers. These aircraft are a key element of America’s national defense posture. Their military value relies strongly on leading-edge technologies. The heavy bombers, along with many of the associated supporting technologies, generate sparse markets outside of the U.S. defense department. When taking into consideration the development

of the cutting-edge technologies required for each new generation heavy bomber, the lead time to design and produce such aircraft is measured in decades.⁴

Based on these characteristics it seems sensible to look into the future and try to identify any trends that might affect the ability of America's defense aviation industry to effectively and efficiently respond to future requirements for heavy bomber aircraft. The first step in this process is to develop a better appreciation of heavy bomber capabilities.

Why Heavy Bombers?

It is necessary to understand why our nation's leaders should be interested in heavy bombers before beginning an analysis of America's bomber industrial base. "The fundamental characteristics that distinguish bombers from other weapons are their long range and their substantial payload capability. They can deliver large, diverse payloads virtually anywhere in the world in a matter of hours. That means they have inherent advantages in situations where massive and/or sustained firepower matter, particularly if the attacks need to be made at long range from relatively safe bases. To the degree that that kind of capability is important, planners should be interested in heavy bombers."⁵

Throughout history heavy bombers have fulfilled key roles in both conventional operations and preparations for nuclear war. "Unless there is a complete reversal of current trends in the world, the possible nuclear role of bombers is going to be much less important in the future than it has been in the past several decades. If so, bombers can make the transition to a conventional role much more easily than other strategic systems. Should the need arise, they could also revert back to their nuclear roles."⁶

As the world moves into the post–Cold War era, America continues to drawdown its defense budget and overall force levels. Political and economic pressures, both foreign and domestic, are causing a continuing decline in the level of forward–based U.S. forces. The result is that fewer alternatives are available for rapidly delivering force during the initial phase of an emerging conflict in an isolated region of the globe. “Indeed, heavy bombers could be the only practical option in some cases of interest, which means they could fill a unique niche in U.S. military capability.”⁷

In focusing on the need for heavy bombers, it would be remiss not to review America’s involvement in the Gulf War. Following his retirement from the United States Air Force, General Charles Horner, Commander of all U.S. and Allied air assets in Operations Desert Shield and Desert Storm during 1990–1991, reflected back on the crisis in Iraq and noted some of the lessons that should have been gained from this recent combat experience. The general stated the “the proliferation of weapons of mass destruction (WMD) and ballistic missiles means that our current strategy of pouring thousands of fighters and hundreds of thousands of troops into our enemy’s back yard is no longer viable. The best hedge against the emerging threat is to shift as much of the power–projection burden as we can—as fast as we can—to long–range systems to fight effectively from beyond WMD range.”⁸ In the December 1996 edition of the *Armed Forces Journal*, Robert Chandler elaborates further on this theme by stating that “America plans to fight tomorrow’s regional war in exactly the same manner as it fought yesterday’s Gulf War. Post–Gulf War revelations about the true size, scope, and maturity of Iraqi’s nuclear, biological, and chemical programs, however, suggest doing so may be a recipe for disaster.”⁹ In discussing the air campaign, General Horner highlighted that the need to

minimize casualties had a significant impact on planning, decision making, and operational effectiveness. “We operated our aircraft at high altitude, above the reach of most Iraqi air defenses. This increased aircraft survivability, but it also made target acquisition more difficult and reduced bombing accuracy.”¹⁰ The leader of the Gulf War air campaign also believes that even though many U.S. and coalition lives were saved by initially using massive airpower rather than employment of ground troops, there is still room for improvement in the next conflict. “Long-range airpower leaves fewer aircrew and support personnel within enemy reach. Stealth technology drastically reduces the chances of our aircraft being shot down.”¹¹

Even provided with the testimony of war-seasoned veterans, there remain those skeptics that continue to question the future need for heavy bombers. To begin discussion of this issue, it is necessary to analyze the rationale supporting future production of these long-range and versatile platforms.

Will Additional Heavy Bombers Really Be Needed?

Despite some views that America’s heavy bomber fleet is seemingly adequate for the foreseeable future, it is within reason to believe that the United States will need to produce additional heavy bombers to address one or more of the following scenarios.

Attrition of the Current Bomber Force

Considering present and probable near-term threats, it is unlikely that a significant number of U.S. heavy bombers will be lost in combat. However, looking into the more distant future, it would be naive to believe that enemy defenses have no possibility of becoming more lethal. More importantly, an aggressor would not have to impose large

losses numerically to significantly affect America's heavy bomber operations. The loss of two B-2 Spirit weapon systems would reduce the currently planned operational stealthy-bomber force by ten percent. While many Americans may have come to believe that deterrence alone will prevent conflict, bombers are, after all, designed, tested, and produced to operate in high-threat environments. In such conditions, attrition is to be expected. If losses are considered a possibility, common sense dictates a replacement strategy should be in hand to mitigate acquisition cost and schedule impacts.

Along with including aircraft loss as a requirement for future production, aging of the present bomber fleet is an important point which must also be taken onto consideration.

Aging of the Present Force

Even if attrition due to enemy attack can be maintained near zero, at some point in time the current fleet's heavy bombers will simply become too old to operate reliably and economically. Dr. Kaminski recently stated that the U.S. Air Force is "embarking upon sustaining engineering programs to allow the B-52H bomber to continue as a component of our strategic forces through 2040."¹² Based on the fact that the "first of 102 B-52Hs was delivered to Strategic Air Command in May 1961,"¹³ this strategic platform will be 80 years old upon retirement. This approach to combat is comparable to General Schwarzkoph using Rickenbacker's Spad bi-plane to fend off the Iraqis in Desert Storm.

What is America's answer if the B-1Bs and B-2s do not remain on active inventory as long as the B-52s? The day will arrive without substantial forewarning when the support and operating costs for a B-52 or B-1B may be greater than the expense of procuring and operating a new heavy bomber over the same period of time (minus the incremental value of the new aircraft). In the long term, America might be in a more

advantageous position if actions to prepare the heavy bomber industrial base had already been put in place.

Bomber fleet attrition and aging indicate that some day, perhaps near term, America will need additional heavy bombers. The question that remains is, when?

The Future Will Require Some Type of Bomber

As explained in the previous two sections, America's heavy bomber force will erode one day, through loss or aging. The question now becomes one of should the United States be concerned about this issue now? The art of warfare may evolve so dramatically in the upcoming 25 years that heavy bombers may no longer be considered an airman's tool of combat. These present key instruments of America's military power may follow the same path of the U.S. Navy's battleship. If it confines America's aerospace industrial base's capability to react to new requirements, taking action now to preserve a heavy bomber production capability may be considered extravagant.

However, some experts believe that our nation's bomber force will continue to be needed well into the future. "Our nation's bomber force, with its combination of immediacy, global range, massive precision firepower, and stealth, gives us the operational flexibility to respond to the full spectrum of national security challenges—from nuclear deterrence and major regional conflict to global terrorism. No other weapon system can hold at risk all the targets this nation deems critical, nor project power as effectively and efficiently."¹⁴

Now that the potential need for additional heavy bombers has been explained, it is important to analyze the present bomber industry to gain a better understanding of this infrastructure's health and future capabilities.

Core Industrial Capabilities

The Bomber Industry

Continuous downsizing, combined with corporate merging, has significantly changed the face of America's aerospace industry. "Aircraft companies produce aircraft—many different types of aircraft. The aircraft industry now includes only four companies currently serving as prime contractors: Lockheed Martin, McDonnell Douglas, Northrop Grumman, and Boeing. These companies regularly team with each other in constantly changing patterns on different commercial and military programs."¹⁵ It is interesting to note that while accomplishing research for this study, further consolidation was witnessed by the merger of Boeing and McDonnell Douglas, strongly indicating that no more than three primary aerospace companies will lead America into the 21st century.

Since the only bomber presently in production is the B-2, carefully analyzing this program's current close-out and production activities will pay dividends tomorrow if additional bombers are required in the near term.

B-2 Spirit—Present Curtailment Status and Production Activities

Since the B-2 Spirit is the only heavy bomber presently in production, understanding the contractors' curtailment, or close-out, status and current production activities will aid in analyzing the aerospace industry's present and future capabilities.

B-2 Curtailment Status. B-2 curtailment specifically refers to the reduction in procurement of B-2s to 21 and the impact of this curtailment on the Northrop Grumman Corporation and the B-2 industrial team. Close-out refers to those activities normally associated with the last production lot buy and the contract close-out effort and includes

activity such as closing down the production line, disposition of government property, and consolidation of data. One visible impact of curtailment is the resulting program concurrency. Production close-out tasks are now being conducted concurrently with (or prior to) completion of the development program and with limited production aircraft delivered. Close-out decisions being made today directly impact the industrial capabilities needed tomorrow to support development, production, and any follow-on requirements.

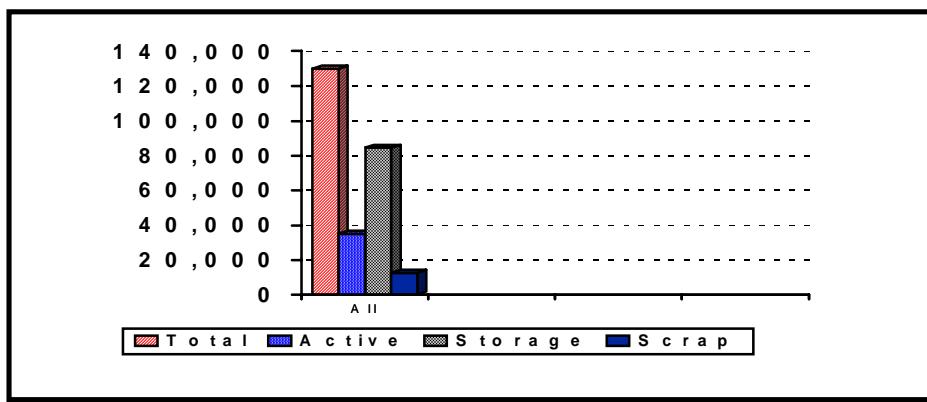


Figure 1. B-2 Curtailment Status—Unique Tooling

A primary area of concern when analyzing B-2 curtailment issues is the government-owned special tooling required for manufacturing and assembling the bomber. Figure 1 depicts the status of B-2 unique tooling. At peak activity, the program maintained nearly 130,000 tools. As of December 1996, 35,000 tools remained active, 15,000 tools had been scrapped, and 80,000 tools were in interim storage until December 1997.¹⁶ Prior to this date USAF officials must decide to continue storage or scrap this tooling.

Another issue of interest when analyzing the present B-2 program is headcount.

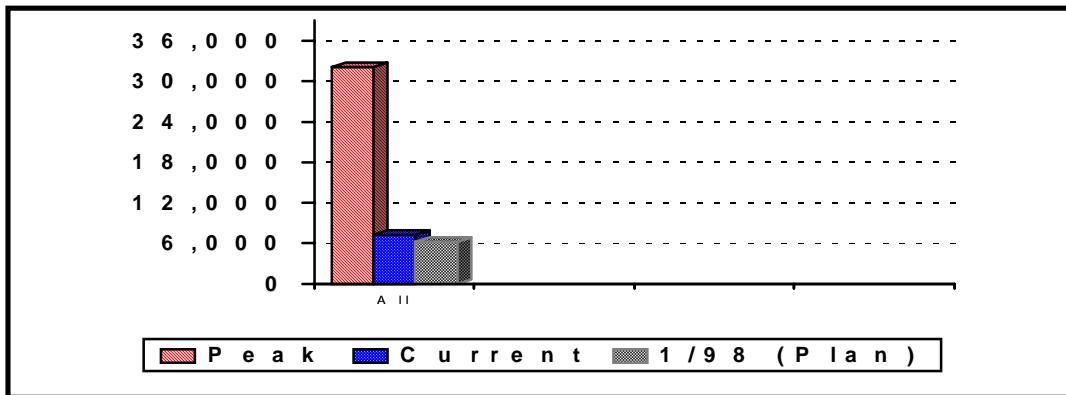


Figure 2. B-2 Curtailment Status—Headcount

Figure 2 illustrates that approximately 32,000 individuals comprised the program during its peak years. As of the end of 1996, this number had been reduced to about 7,000 and projections for January 1998 reflect further downsizing.¹⁷

Analyzing B-2 curtailment alone is insufficient. Consideration of present production activities are also important in understanding the overall picture of today's bomber production base.

B-2 Production Activities. As of December 31, 1996, six flight test aircraft have been produced and 13 production B-2s have been delivered to Air Combat Command. The final two production aircraft will be delivered in 1997. The six flight test aircraft and the first 13 production aircraft must undergo modifications to bring each bomber up to full operational capability. This effort is already underway with six aircraft currently in the modification line and mod line deliveries of fully capable operational aircraft ranging between late 1997 and early 2000.¹⁸

The present B-2 production capability is rapidly coming to an end and 1997 will significantly impact this process by witnessing the completion of flight test and delivery of

the last production aircraft. Since this time will also continue to observe the erosion of the fragile network of suppliers and subcontractors required to manufacture additional B-2s, it is imperative to analyze the significance of experience in designing and producing aircraft.

Notes

¹ Honorable Paul G. Kaminski, The Under Secretary of Defense for Acquisition and Technology, keynote address to the Strategic Systems Industrial Symposium, U.S. Strategic Command, Offutt AFB, Ne., 26 September 1996.

² Jeffrey A. Drezner et al., *Maintaining Future Military Aircraft Design Capability*, RAND Report R-4199-AF (Santa Monica, Calif.: RAND, 1992), 1.

³ "The World That Came in From the Cold," *Executive Speeches*, June/July 1994, 42.

⁴ Drezner et al., 1.

⁵ Glenn C. Buchan and David R. Frelinger, *Providing an Effective Bomber Force for the Future*, RAND Report CT-119 (Santa Monica, Calif.: RAND, May 1994), 2.

⁶ Ibid.

⁷ Ibid.

⁸ General Charles A. Horner, USAF (Ret), "What We Should Have Learned in Desert Storm, But Didn't," *Air Force Magazine*, December 1996, 53-54.

⁹ Robert W. Chandler, "New Power-Projection Calculus," *Armed Forces Journal*, December 1996, 14.

¹⁰ Horner, 55.

¹¹ Ibid.

¹² Kaminski.

¹³ "B-52 Stratofortress," *USAF Fact Sheet*, November 1996, n.p.; on-line, Internet, 20 January 1997, available from http://www.dtic.dla.mil/airforcelink/pa/factsheets/B_52_Stratofortress.html.

¹⁴ Prepared Testimony of General John M. Loh, Commander, Air Combat Command, Department of the Air Force, to the House National Security Committee, The Subcommittee on Procurement, subject: USAF Bomber Requirements, 6 April 1995.

¹⁵ TASC Incorporated, *Heavy Bomber Industrial Capabilities Study Final Report* (Arlington, VA: TASC Incorporated, December 1995), 19.

¹⁶ Briefing, Northrop Grumman Military Aircraft Systems Division, subject: B-2 Curtailment Metrics Review, 16 January 1997.

¹⁷ Ibid.

¹⁸ James Gifford, Northrop Grumman Military Aircraft Systems Division, interviewed by author, 10 January 1997.

Chapter 2

The Role of Experience in Aircraft Production

The question we must resolve is how to sustain the unique industrial capabilities (including human talent—people) needed to develop, produce, and support strategic systems now and in the future.

—Honorable Paul G. Kaminski

In assessing the importance of experience, relying on the insight of seasoned veterans in both the defense aerospace industry and associated government agencies appears to be a realistic guide used by experienced researchers in past studies. Research analysts from the RAND Corporation conducted interviews of approximately 40 senior level officials of the aerospace industry. These individuals were from varied professional areas including advanced technologies, business development, and engineering, and included many at the vice president level.¹ After careful verification of information obtained through these interviews, and further discussion with experienced government acquisition officials, the results concerning experience seem quite clear. “Experience enhances the ability of design engineers to mitigate risk through anticipation of future problems.”² RAND further expounds on the importance of experience in a later publication by stating, “the role of experience—of steadily building up and maintaining expertise over time through constant ‘learning by doing’—plays a critical role in the cost-effective design and development of successful military aircraft.”³ Problems suffered in recent major weapon systems such as

the U.S. Navy's A-12 Avenger and the U.S. Air Force's B-1B Lancer programs strongly indicate that a lack of experience led to mistakes which impacted cost, schedule, and/or performance criteria. "A declining experience level has been a contributing factor to the problems we observe in many aircraft programs."⁴

Some aerospace experts believe that the infusion of computer simulation into the design procurement process alleviates the need for experience. "While simulation and automation...will certainly help, it cannot substitute for...intuition and inspiration. Furthermore, such automation is only marginally effective when dealing with new and untried technologies because the basic information needed for the computation algorithms is missing or of low fidelity."⁵

The RAND Corporation has also studied the issue of transferability of design experience between types of aircraft or other complex systems. "There is some interchangeability of experience across military aircraft types and possibly even from commercial aircraft. However, we do not believe that this significantly resolves the problem. Most other systems will also be facing the same sorts of problems, and, more to the point, expertise at designing and developing complex aircraft systems comes only from the direct experience of designing and developing such systems. That experience helps engineers and managers anticipate (and prevent) problems on their next project."⁶

From all indications, experience seems to have a direct correlation in efficiently designing and producing aircraft. However, this overarching conclusion implies that experience gained in producing one type of aircraft (fighters) would be equally valuable when transferred to manufacturing a different class of aircraft (bombers). Since this

perception is not entirely accurate, it is beneficial to focus on the value of experience provided from other type aircraft programs to heavy bombers.

Relevance to Bombers of Experience From Other Aircraft Programs

The transport and fighter industrial bases should be able to provide a substantial amount of expertise to future heavy bomber programs. However, there are many critical areas that will not be covered at all if no heavy bomber work is accomplished in the interim time. The following paragraphs examine those unique elements of bomber design and production that cannot draw on experience in other aircraft programs. The areas of technical/engineering, manufacturing, and testing are included.

Significantly important in the area of engineering is that concerning weapon handling that is peculiar to heavy bomber missions. Ground handling and loading of the weapons are important topics in this area in addition to the actual separation and release of the weapons. The fact that a bomber's weapons bays are considerably larger than those found on fighters is unique. Associated components that are unique to bombers are the large weapons bay doors that are required to operate at high speed. Finally, the mechanisms that comprise the weapon release and separation systems also have a profound and extensive impact on the heavy bomber design.

Experience with fighter and transport aircraft will not be adequate to guide heavy bomber design and production personnel due to the fact that heavy bomber operations are simply quite different. In the early phases of designing the weapon system for reliability, maintainability, and supportability, having a firm understanding of the systems operating environment and mission characteristics is paramount.

When analyzing the area of manufacturing, the issue of expertise, as discussed relative to engineering, may not be the limiting factor. The concern may be focused more on available capacity. The final assembly areas of fighter aircraft manufacturing facilities would typically be unsuitable for heavy bomber production. In the case of the B-2, not only were large production facilities required, but enormous tooling fixtures (e.g., 90 foot autoclaves) were also needed to accommodate manufacturing the aircraft's massive wing sections. In reviewing commercial aircraft facilities, the functional differences are found to be so significant as to generate the requirement for entirely separate final assembly and check-out facilities for heavy bombers. Timing and priority of the bomber program would also be important variables relative to other commercial and military aircraft programs.

In the area of aircraft testing, radar signature testing, in addition to static and fatigue testing, are the most notable areas of interest. Presently such facilities exist and attention should be focused on preserving them. However, even with preservation of these test structures, the expertise of testing heavy bombers will gradually erode over time if no large aircraft designs are tested. A loss of experience will directly impact the workforce's learning curve which will affect cost, schedule, and quality of future testing accomplished.

It is important to note that none of the lapses in existence, availability, or concentration of experience would render a heavy bomber program impossible. However, these variables would have a direct impact on cost, schedule, and performance—three parameters of vital importance in today's environment of decreased defense spending.

With the introduction and overwhelming success of stealth technology, it is within sensible bounds to predict that future weapon systems will include some degree of this engineering principle. Based on the time and costs America has already invested in

stealthy weapon platforms, it is important to next review the significance that experience plays in the period of stealth technology.

Role of Experience During the Stealthy Era

The serious problems resulting in cancellation of the Advanced Tactical Aircraft, or A-12, program may best illustrate the meaningful role of experience in advanced composites and other stealth technologies.

In the Research and Development (R&D) phase of a complex major weapon system, there are many variables which could contribute to cost overrun and schedule slippage. In reviewing the A-12 situation, “clearly...the R&D program had run into serious problems when cancellation occurred, and many of these problems appear to have been caused by the contractor’s lack of experience in critical composite technologies related to stealth.”⁷ Selected verbiage from the official inquiry into the A-12 investigation reflects the impact that inexperience can generate. “The primary problem encountered during FSD [*Full Scale Development*] was weight growth due to the thickness of the composite material necessary for the structural strength required to support the stress and loads experienced by carrier-based aircraft. Both contractors [*McDonnell-Douglas and General Dynamics*] have limited experience in building large composite structures and, in large measure, have had to develop the technology as the program progressed.”⁸

Investigating the relevance of experience from other aircraft programs, in addition to analyzing the role of experience witnessed during the stealthy era, strongly indicate the overall importance of this accumulation of knowledge and skill. Based on this conclusion,

it is valuable to continue this general analysis by specifically focusing on the impact of restart experience in bomber production.

Notes

¹ Jeffrey A. Drezner et al., *Maintaining Future Military Aircraft Design Capability*, RAND Report R-4199-AF (Santa Monica, Calif.: RAND, 1992), 14.

² Ibid.

³ Mark A. Lorell, *Bomber R&D Since 1945, The Role of Experience*, RAND Report MR-670-AF (Santa Monica, Calif.: RAND, 1995), 1.

⁴ Drezner et al., 16.

⁵ Ibid.

⁶ Ibid., 50.

⁷ Lorell, 58.

⁸ Ibid.

Chapter 3

Aircraft Production Restart Experience

The problem with defense is how far you can go without destroying from within what you are trying to defend from without.

—Dwight D. Eisenhower

Analyzing past aircraft production restart cost and schedule experience will aid in understanding the future applicability of this information. Breaks in production lines are not new and have generated a great number of studies in an attempt to gain a better understanding of the effect of such action. “Although experience with aircraft production restart is not wide-spread, all U.S. military services have had occasion to reopen production lines when circumstances indicated that doing so was the most practical means to obtain additional systems.”¹

In reviewing many of the original models used for such studies, much of the analysis relied primarily on the cost impact relative to production labor only. “None includes all the functional cost elements, i.e., engineering, tooling, quality assurance, etc.; and, all ignore nonrecurring costs. Also, most models are based on factory experience with components, line replaceable units, or small systems for which total production hours are measured in the thousands or tens of thousands.”² Relying solely on the results of such limited studies could result in erroneous conclusions. When considering the production restart costs of a major weapon system, a credible analysis must take into consideration

production activity data relative to an effort consisting of millions of factory hours versus thousands. The following information focuses on restart experience with the B-1 bomber program.

B-1 Restart

In analyzing a heavy bomber program which experienced production restart activities, the B-1 Lancer is the most recent example. Following only one year of production, President Jimmy Carter canceled the B-1A program in 1977. “The program had built up to a maximum level of about 9,000 people, with most work done at El Segundo, CA and at Site 3 at Palmdale, CA. At the completion of the program, three flight test aircraft, one ground test aircraft, and 27 engines had been ordered.”³

From 1977 to 1982, Rockwell International (RI), the prime contractor, continued to advocate restarting the program and, using capital assets, continued development, flight test, and studies. Technicians and engineers were loaned to other aerospace companies during this timeframe. As history reflects, this corporate gamble paid off for Rockwell.

After a span of nearly seven years had passed, RI received contract direction in 1982 for Engineering and Manufacturing Development and initial production and long-lead items for a new version of the heavy bomber, the B-1B. It should be noted that “the B-1 never achieved a true production status during the initial phase, and substantial development remained to be accomplished during the ‘restart’ phase.”⁴

Also worth noting is that the 1995 *Heavy Bomber Industrial Capabilities Study* completed by The Analytical Sciences Corporation, included the B-1 restart scenario to

illustrate “the relative ease of restarting the program after a seven year gap suggests that proportional reductions in schedules and costs might also be achieved for a B-2 restart.”⁵

In using the B-1 restart activity for making present and future decisions, America’s decision makers must remember that the overall defense environment was considerably different in the early 1980s than it is today. The defense budget had not begun its downward tail spin and major aerospace corporations were more willing to make capital investments based on mere possibilities. Also, the “loaning” of aerospace technicians and engineers to other aerospace companies is a practice of the past. A significant percentage of these talented individuals are completely leaving the nomadic defense aerospace world for more stability elsewhere. America’s strategic environment has drastically changed and basing future B-2 reconstitution decisions solely on B-1 restart experience is comparable to Saturn using the Model-T for future automobile production decisions. America’s decision makers must remember that “if the industry falls into serious decline and a generation of skilled workers is allowed to dissipate, restarting a production line might be less practical than recent experience has indicated.”⁶

In analyzing previous aircraft production restart programs, each situation was unique, thereby providing limited conclusive details relative to future restart decisions. However, there are numerous general lessons which have been learned that do provide sound guidance in helping prepare for future program restart situations.

Production Restart—Lessons Learned

In years past, numerous contractors with manufacturing lines did not take into consideration “smart shutdown” activities that would enable the production line to be

efficiently reopened. However, in today's environment of ever-changing security threats to the U.S. and the continuing decline in the defense budget, many defense contractors have realized that uncertainty over the sufficiency of current defense systems raises the issue concerning the ability to reopen closed production lines as an important option.

To prepare for a "smart shutdown" of production activities, there are numerous areas which must be considered. The RAND Corporation devoted an entire chapter on this issue in their 1993 publication, *Reconstituting a Production Capability*. All of the actions required to minimize confusion and enable an efficient restart must be identified. RAND considered the following four questions a good outline to achieve this outcome.⁷

1. What needs to be preserved?
2. What is the cost?
3. When should actions be taken?
4. What are possible influences beyond program control?

The B-2 program has included these four areas of interest in addition to many others in developing the USAF/Northrop Grumman Curtailment Program. The curtailment approach outlined in this plan is based on a balance of three primary considerations:⁸

1. Protecting program capability
2. Managing program affordability
3. Ensuring contract compliance

"The cost-effective protection of program capability is the key to the B-2 curtailment program."⁹ Capability requires the retention of tooling and special test equipment, program data, and in selected instances, specific technical skills to complete existing contract requirements for the present B-2 program. This includes completion of the Engineering and Manufacturing Development program and final delivery of 21 fully

operational aircraft. Protecting the Air Force's capability to operate and maintain these stealthy aircraft in a post-production environment is also an important decision.

Oftentimes capability considerations encourage the retention of program assets, whereas program affordability thresholds pull in the opposite direction. "Expeditious disposition of program assets, as soon as they become excess to immediate needs, reduces program costs. The key to successful curtailment will be in the decision making process of which assets to retain and for what period of time. The correct balance of protecting capability and cost effectiveness will retain assets with high probability for future use and/or significant replacement cost (dollars or lead time). Those with very low probability of future use and/or low replacement cost will be discarded. Program unknowns can make that determination high risk, causing decision deferral."¹⁰

The USAF/Northrop Grumman B-2 Curtailment Program consists of six areas. The first area, program management, deals with the management approach, philosophy, and overall objectives of the curtailment program. Property disposition is the second area and focuses on B-2 physical assets with special attention being placed on disposition of government-owned special tooling. Even though Northrop Grumman (NG) capital property disposition is also addressed, it should be noted that the U.S. government has no control over corporate decisions regarding these assets. The third area, critically important to both USAF and NG future capability, concerns the disposition of program data. The fourth area deals with security close-out requirements. The close-out of B-2 development and production facilities is the focus of the fifth area. Finally, the curtailment of the subcontractor industrial team is the heart of the sixth area.

In comparing the present USAF/Northrop Grumman Curtailment Program with RAND's outline for a "smart shutdown" of production activities, it is apparent that the B-2 effort has more than sufficiently addressed the key areas of consideration. However, it should also be noted that even though government-owned special tooling is presently being protected through December 1997 and program critical data is adequately being preserved for future requirements, the most critical assets, those talented human resources that are the cornerstone of the engineering, production, and supplier bases, are not protected and will continue to erode with time.

If applied correctly, this general information will significantly reduce cost and schedule impacts for procurement of additional bombers. It was this "correct application," in addition to uncertainty of the proper bomber force and concern over the erosion of the aerospace industrial infrastructure, that generated recent activity to preserve the heavy bomber production capability. This activity is the focus of the next chapter.

Notes

¹ John Birkler et al., *Reconstituting A Production Capability*, RAND Report MR-273-ACQ (Santa Monica, Calif.: RAND, 1993), 5.

² Ibid., 6.

³ TASC Incorporated, *Heavy Bomber Industrial Capabilities Study Final Report* (Arlington, VA: TASC Incorporated, December 1995), 43.

⁴ Birkler et al., 11.

⁵ TASC Incorporated, 43.

⁶ Birkler et al., 20.

⁷ Ibid., 22.

⁸ Northrop Grumman *B-2 Bomber Curtailment Program Plan*, January 1996, 1-2.

⁹ Ibid.

¹⁰ Ibid.

Chapter 4

Recent Heavy Bomber Industrial Base Activity

The higher you go in rank and responsibility, the greater the need to get all the facts as the best means of avoiding mistakes in decisions, and the greater need for carefully considered good judgment.

—Major General Aubrey “Red” Newman

Members of Congress, the military, and the contractor community voiced concern that the imminent completion of the B-2 program could result in a significant void in America’s capability to produce additional bombers in a timely and efficient fashion in response to potential global conflicts. Congressional debates continued through the end of calendar year 1994 without resolution on the need for additional heavy bombers. A majority of Congressional members did accept the fact that if more bombers were the correct answer, maintaining the ability to produce the aircraft in a timely and efficient manner was paramount. This belief generated recent activity on the part of America’s political leadership.

Congressional Direction

The Congressional Fiscal Year (FY) 1995 Authorization and Appropriations Acts required the Secretary of Defense to conduct a study to analyze the alternative strategies for increasing bomber force capabilities. To be included in this analysis, DOD was to

conduct a study to “determine those core bomber industrial capabilities that are needed to maintain the ability to design, develop, and produce bomber aircraft in the near term and in the long term and that would take an extended period of time or substantial expense to regenerate; and, are in imminent danger of being lost.”¹

Accompanying this Congressional direction was \$125 million to complete these studies and to sustain the bomber industrial base. Congressional intent for use of these funds was for DOD to protect the option to produce additional B-2 aircraft until a final decision on heavy bombers was reached. Of this total dollar value, approximately \$94.7 million was available for protecting the B-2 industrial base.

The Congressional intent of the bomber industrial base study was to examine what actions DOD should take to preserve for one year the possibility of producing additional B-2 bombers in the future, at a reasonable cost and schedule, until the bomber force requirement decisions were made. The Department of Defense, coupled with the appropriate representatives of the aerospace industry, took immediate action to address this Congressional direction.

DOD and Industry Reaction

A USAF/Northrop Grumman joint team developed a plan in response to this Congressional and subsequent DOD direction. The effort, officially referred to as the B-2 Production Base Preservation (PBP) Program, was designed to “preserve the option to purchase additional fully operationally B-2 bombers at a reasonable cost and schedule under the B-2 Sustained Low Rate Production Program.”²

The PBP Program included the following tasks: (1) preserving supplier base industrial base capabilities, (2) preservation of suppliers of unavailability of production parts, (3) revise/update production work orders and manufacturing plans, (4) re-facilitization and tooling restoration, and (5) return of government owned/furnished special tooling to storage in the event that no follow-on B-2 production was authorized.³

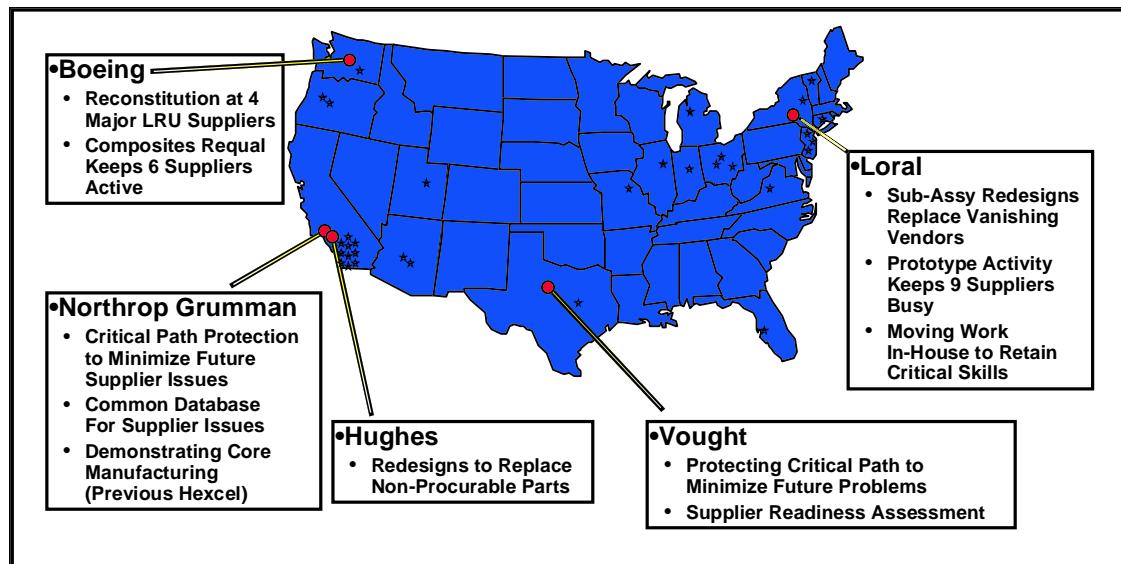


Figure 3. B-2 Production Base Preservation Program—Suppliers Involved

Northrop Grumman B-2 Division, Vought, Boeing, Hughes, and Loral were placed on contract February 12, 1995 to support the B-2 PBP Program. Figure 3 shows the supplier locations that received PBP funding and specifically addresses the five major contractors involved in this effort.⁴

Moog and Rockwell Collins were put on contract June 1995 and October 1995 respectively. In addition to Northrop Grumman, “the efforts of these contractors resulted in 85 other companies being funded to support the various PBP activities.”⁵

The USAF/Northrop Grumman B-2 PBP Program was successfully completed on schedule and within cost. More important, however, this unprecedented effort

successfully achieved the Congressional intent of ensuring the B-2 production base remained a viable option for at least one year.

To satisfy Congress' direction to determine those core bomber industrial capabilities needed to design, develop, and produce bombers, the defense department contracted the expertise of a Washington DC-based research company, The Analytical Sciences Corporation.

TASC *Heavy Bomber Industrial Base Capabilities Study*

The Analytical Sciences Corporation (TASC) was contracted by the Office of the Secretary of Defense to conduct an analysis of the bomber industrial base in response to the Congressionally-mandated *FY1995 Heavy Bomber Force Study*. The study was to determine the capabilities and technologies necessary to design, develop, and produce bomber aircraft. The study was also to assess the condition of current potential suppliers. Finally, the study was to assess alternative options, including associated smart shut-down and start-up costs.

The TASC analysis addressed the following two critical questions the DOD was being faced with concerning future heavy bomber procurement. “Will reduced procurement result in the loss of industrial capabilities required to design, develop, produce, and maintain advanced military systems? And, will today’s acquisition decisions do irreparable harm to our ability to obtain new systems when they are needed in the future?”⁶

“TASC’s approach involved three tasks. The first was to identify the core capabilities associated with heavy bombers and determine whether these capabilities are dependent on continued B-2 production. This task also assessed the likelihood that essential capabilities

would be retained through their application to other military and commercial aircraft programs. The remaining tasks examined the aircraft industry's ability to restart the B-2 or initiate a new bomber program when required.”⁷

TASC provided three findings relative to their analysis focusing on industrial capabilities for the B-2. The first finding was that “core industrial capabilities required for B-2 and future bombers will not be endangered if the B-2 program ends with 21 aircraft.”⁸ This result indicated that bomber programs do not utilize industrial capabilities that are unique to solely this type of aircraft. “Rather, bomber programs are served by many of the same prime and lower-tier companies that participate in other military and commercial aircraft programs.”⁹

The TASC effort also found that “B-2 technology, design, and production requirements are no longer new.”¹⁰ A third finding was that innovative sources for all types of military aircraft will remain healthy.¹¹

The TASC final report concluded its findings of industrial capabilities for the B-2 by stating that “the bottom line of our analysis of B-2 industrial capabilities is that continued production of B-2 aircraft is not a prerequisite to our ability to restore bomber production in the future.”¹²

Fiscal Year 1995 witnessed a great deal of activity relative to heavy bombers. Of specific interest to this report is the TASC study concerning the bomber industrial base. The next and final chapter of this report focuses on the shortfall of this study and provides recommendations to mitigate cost and schedule impacts for future heavy bomber production.

Notes

¹ Public Law 103-337—October 5, 1994, Section 133, Heavy Bomber Force Requirements.

² Northrop Grumman *B-2 Bomber Production Base Preservation Program Plan*, March 31, 1995, 2.

³ *Ibid.*, 3-4.

⁴ Northrop Grumman *B-2 Bomber Production Base Preservation Program Final Report*, June 30, 1996, 30.

⁵ Northrop Grumman *B-2 Bomber Production Base Preservation Program Final Report Executive Summary*, June 30, 1996, ES-6.

⁶ TASC Incorporated, *Heavy Bomber Industrial Capabilities Study Final Report* (Arlington, VA: TASC Incorporated, December 1995), I.

⁷ *Ibid.*, 12.

⁸ *Ibid.*, 70.

⁹ *Ibid.*

¹⁰ *Ibid.*

¹¹ *Ibid.*

¹² *Ibid.*

Chapter 5

Conclusions and Recommendations

The B-2 is the only weapon system in the US inventory free of range, survivability, and lethality limitations that plagued us during the recent Iraqi crisis. Given the B-2's obvious and unique utility in the new global strategic environment, it is difficult to comprehend how the Pentagon could so actively resist expanding the fleet.

—General Charles. A. Horner, USAF (Ret)

Regardless of the correct number of bombers, aircraft alone simply do not equate to airpower. General Billy Mitchell, as early as 1921, wrote about “the importance of a strong civil aviation industry, the role of government in building that industry, and of the importance of instilling an ‘airmindedness’ in the people.”¹ Mitchell later stated that, “It must not be thought that because the United States has capabilities of manufacturing aircraft more quickly and in greater numbers and more cheaply than other countries, that we should wait until another contest has started, to build aircraft. This is a most decidedly mistaken policy and should not be entered into.”²

America’s current long-range bomber production program will cease in late 1997 with the delivery of the final B-2. In a 3 May 1995 letter to Senator Strom Thurmond, Chairman, Committee on Armed Services, Dr. Paul Kaminski, The Under Secretary of Defense for Acquisition and Technology, stated that “based upon the results of the *FY95 Heavy Bomber Force Study*...the planned force can meet the national security

requirements of two nearly simultaneous major regional contingencies (MRC) for anticipated scenarios and postulated excursions.”³ However, only one month prior to Dr. Kaminski’s remarks, a senior Air Force leader provided contrary affirmation.

In his testimony to the House National Security Committee, The Subcommittee on Procurement, on 6 April 1995, the Commander, Air Combat Command, General John M. Loh, stated that he was “concerned that we may not have enough bombers to meet all of our operational demands. Our analysis tells us that we will need 100 deployable bombers in the initial days of a major conflict to provide an aggressive and powerful response to an enemy offensive. Should a second major conflict arise during the first MRC, we will have to swing a portion of our bomber force from the first conflict to the second.”⁴ The analysis to which Loh refers was accomplished by Air Combat Command in 1995, and was subsequently supported by the Bottom-Up Review. The study indicated that the U.S. would need approximately 180 bombers to sufficiently support America’s nuclear mission and to meet its conventional requirements.⁵ Discussing the shortcomings of the “swing” strategy, Loh further stated, “We should keep in mind that this strategy is untried, and could stretch our combat forces, strategic lift, and logistics capability very thin. If we are unable to swing bombers in the two MRC scenario, we will not have enough bombers to deploy 100 to each MRC. So it is important that we maintain sufficient numbers of bombers for the long term.”⁶

America’s diverse and advanced economy will presumably always be able to design or manufacture a specific component or weapon system. In reference to the findings of The Analytical Science Corporation’s (TASC) *Heavy Bomber Industrial Capabilities Study*, it becomes clear that anything invented and produced once can be reproduced at a later date.

Thus, the primary concern becomes not whether the U.S. will be able to physically produce bombers again once the nation's current capability is allowed to dissipate, but whether America could produce those additional bombers in the future at *acceptable costs* and *within required timelines*. By restricting the focus of the production debate to just looking at the mental and physical capital necessary to re-start production in the future, we ignore the much larger issue of practical feasibility. The real-world issues of time and money needed to restart bomber production were not addressed in the TASC final report with sufficient detail to allow our nation's political leaders to make informed decisions.

Estimations of B-2 restart costs vividly illustrate the importance of these practical considerations. “In the two years since the end of the B-2 Production Base Preservation Program, Northrop Grumman estimates that B-2 restart costs have increased by over \$1 billion. In addition, the lead time to the first aircraft delivery has grown by nearly 15 percent.”⁷ Cost growth will continue for some time and more important to national interests, the lead time to having additional warfighting capability on the flightline will also continue to increase. This growth will ultimately flatten out and at some time a new development program will be the more cost-effective solution. However at that point, using data extrapolated from the B-2 program, America would be over a decade away from having new bombers available to operational commanders. That will be of little comfort if the U.S. realizes in five years that today's bomber force structure decisions were wrong.

One way to maintain a bomber production base is to continue producing the aircraft while the production line is “warm.” If we accept the logic that future bomber production may be likely, then a prudent course for the nation at this time may be to embark on a

low-rate production program while B-2s are as affordable as they ever will be. Precedent for such a low-rate production effort with industrial base objectives can be found in the nation's other stealthy, long-range power projection system, the Navy's nuclear submarine program. However, based on DOD's present decision not to acquire more B-2s and the fact that the intent of this research is to analyze the bomber industrial base rather than promote procurement of additional bombers, the following two recommendations are provided for consideration.

The first recommendation is to strengthen the present B-2 curtailment program by extending interim storage and preservation activities for five years for selected government-owned property with reevaluation at that time. This near-term action would "preserve the most critical capabilities and...reduce risk in restarting production."⁸ A second approach would be to provide additional funding to procure and store selected company-owned or capital equipment—a critical area not addressed in the present plan. Considering the initial cost of all the tooling required for B-2 production, a modest investment to accomplish these two actions would dramatically reduce future costs and significantly decrease lead time if additional B-2 bombers are required in the future.

Maintaining the B-2 industrial capability is most effectively accomplished by maintaining the existing industrial team. Any activity that places business into the many contractors involved on the program keeps those facilities active and perpetuates an active pool of B-2 knowledge. Spare parts procurement, repair contracts, depot support, upgrade programs, and any related program activity will keep industrial base member resources dedicated to the B-2 program. This, in turn, reduces the risk, lead time, and cost of a subsequent restart. Consequently, the second recommendation of this paper is

for the USAF's B-2 System Program Office and the Northrop Grumman Military Aircraft Systems Division to jointly develop a coherent industrial strategy which compares B-2 post-production support requirements and capabilities against potential bomber production restart needs. A coherent strategy could be designed to both support the present B-2 fleet and increase the probability of an affordable restart. Such a strategy would include a long-term roadmap for weapons systems upgrade and modernization; consider the industrial base impact to spare parts ordering policies; and deal with component obsolescence issues on an annually funded basis. The suppliers important for B-2 production are, for the most part, the same vendors required to support the present fleet. Parts unavailable for future production will also not be available for future spares requirements.

The appropriate number of long-range bombers and the importance of the bomber's supporting industrial base will continue to be issues of debate. The TASC findings stated that bomber production capabilities are not unique and that the "cessation of B-2 production will not prevent the nation's aircraft industry from building bombers in the future."⁹ Absent in these findings, however, were two extremely important variables—time and money. The B-2 industrial base took twelve years and a \$24 billion investment to develop.¹⁰ With technology advancing at exponential speeds and America craving to exploit the peace dividend, neither lead-time nor budget of that magnitude may be available in the future.

As America is confronted with a declining defense budget, it continues to face a wide array of security challenges. It is inevitable that through attrition and aging, our nation's bomber fleet will need to be complemented in the next 10 years with additional bombers.

America's only active bomber industrial capability lies in the B-2 production base, and this infrastructure is quickly being dismantled as the final aircraft are being produced. Measuring America's bomber industrial capability solely on theoretical capabilities provides distorted findings that mislead our nation's decision makers. The practical feasibility of procuring bombers in the future at *acceptable costs* and *within required timelines* is the bottom line and should not be overshadowed by hidden agendas or preconceived notions.

By enhancing the B-2 curtailment program and developing a coherent industrial strategy, the nation more efficiently supports the present B-2 fleet and, to a limited degree, protects the option of being able to produce additional Spirit bombers if so directed as a result of the presently ongoing *Deep Attack Weapons Mix Study*.

Notes

¹ Colonel Phillip S. Meilinger, *10 Propositions Regarding Air Power* (School of Advance Airpower Studies, Air Force History and Museums Program, 1995), 61.

² William Mitchell, *Winged Defense* (1925; reprint, New York: Dover Publications, 1988), 198.

³ Dr. Paul G. Kaminski, The Under Secretary of Defense for Acquisition and Technology, to Chairman, Committee in Armed Services, U.S. Senate, letter, no subject, 3 May 1995.

⁴ Prepared Testimony of General John M. Loh, Commander, Air Combat Command, Department of the Air Force, to the House National Security Committee, The Subcommittee on Procurement, subject: USAF Bomber Requirements, 6 April 1995.

⁵ Ibid.

⁶ Ibid.

⁷ James Gifford, Northrop Grumman Military Aircraft Systems Division, interviewed by author, 20 March 1997.

⁸ TASC Incorporated, *Heavy Bomber Industrial Capabilities Study Final Report* (Arlington, VA: TASC Incorporated, December 1995), 58.

⁹ Ibid., 70.

¹⁰ Briefing, B-2 System Program Office and Northrop Grumman Corporation, subject: 1995 B-2 Industrial Base Preservation: A Team Approach, 9 November 1994.

Glossary

A-12 Avenger. A subsonic, carrier-based, all weather stealth attack aircraft. The A-12 was essentially a delta flying-wing without any major tail-fin structures or afterburners. The project, which was begun in 1984, was canceled by the Navy and the DOD in January 1991 because of major cost overruns and delays in the delivery schedule. (Dictionary of the Modern United States Military, 2)

air campaign. A connected series of operations conducted by air forces to achieve joint force objectives within a given time and area of operations. (Air Force Manual 1-1, Volume II, 270)

attrition. The reduction of the effectiveness of a force caused by loss of personnel and material. (Department of Defense Dictionary of Military and Associated Terms, Joint Pub 1-02, March 1994, 40)

B-1B Lancer. A long-range bomber powered by four augmented turbofans and equipped with avionics designed to allow penetration of enemy airspace. The B-1B is a four crew bomber that has three internal weapons bays which can carry various weapons or auxiliary fuel tanks. (*World Military and Civil Aircraft Briefing*, February 1994, 1)

B-2 Spirit. A flying wing with smooth surface contours, unbroken outer surface lines, and extensive use of composites. It has four recessed engines with top-of-wing inlets and exhaust. The B-2 is a two crew stealthy bomber designed to minimize its radar, infrared, electromagnetic, acoustic, and visual observable signatures. (B-2 Stealth Bomber Fact Book 1995, 5)

B-2 Sustained Low Rate Production Program. Northrop Grumman Corporation's proposed program for continued B-2 production. The key features of the proposed program were sustained low rate production in a build-to-print environment. (Northrop Grumman B-2 Sustained Low Rate Production Program Executive Summary)

ballistic missile. Any missile which does not rely upon aerodynamic surfaces to produce lift and consequently follows a ballistic trajectory when thrust is terminated. (Department of Defense Dictionary of Military and Associated Terms, Joint Pub 1-02, March 1994, 45)

bomber industrial base. That portion of the overall defense aerospace industrial base whose skills and facilities develop, produce, and maintain heavy bombers. (thesis definition)

capability. Includes critical technologies and processes, facilities, capacity/utilization, employment trends/forecasts, and single/sole/foreign source issues. (Air Force Industrial Base Assessment of the Aircraft Sector, December 1993, iv)

coalition. A force composed of military elements of nations that have formed a temporary alliance for some specific purpose. (Department of Defense Dictionary of Military and Associated Terms, Joint Pub 1-02, March 1994, 71)

conventional operations. Operations using nonnuclear weapons. (thesis definition)

Deep Attack Weapons Mix Study. A cross-service review evaluating the different combinations and quantities of deep attack capabilities—both the munitions themselves and the delivery platforms—to ensure that the U.S. has the most cost-effective and operationally sound force. It is a follow-on to the Congressionally-directed *Heavy Bomber Study* that was completed in May 1995 and is under the direction of an oversight committee co-chaired by the Under Secretary of Defense for Acquisition and Technology and the Vice Chairman of the Joint Chiefs of Staff. Conducting such a study was one of the major recommendations of the 1995 Commission on Roles and Missions and the study's results as they are available will be used to develop the Fiscal Year 1998 and Fiscal Year 1999 defense programs. (The White House, Statement by the Press Secretary, Deep Attack Weapons Mix Study Fact Sheet, 8 February 1996)

defense aerospace industrial base. The combination of people, institutions, technological know-how, and facilities used to design, develop, manufacture, and maintain the weapons and supporting defense equipment needed to meet U.S. national security objectives. The base consists of three broad components: a research and development component, a production component, and a maintenance and repair component, each of which includes private and public-sector employees and facilities. The base can also be divided into three tiers: prime contractors, subcontractors, and parts suppliers. (*Redesigning Defense: Planning the Transition to the Future U.S. Defense Industrial Base*, 3)

deterrence. The prevention from action by fear of the consequences. Deterrence is a state of mind brought about by the existence of a credible threat of unacceptable counteraction. (Department of Defense Dictionary of Military and Associated Terms, Joint Pub 1-02, March 1994, 115)

heavy bomber. Also referred to as a long-range bomber, an aircraft designed for a tactical operating radius of over 2,500 nautical miles at design gross weight and design bomb load. (Department of Defense Dictionary of Military and Associated Terms, Joint Pub 1-02, March 1994, 221)

infrastructure. The basic facilities, equipment, and installations needed for the functioning of a system. (Webster's II New Riverside University Dictionary, 1984)

payload. The load which the vehicle is designed to transport under specified conditions of operations, in addition to its unladen weight. (Department of Defense Dictionary of Military and Associated Terms, Joint Pub 1-02, March 1994, 286)

Under Secretary of Defense for Acquisition and Technology. The principal staff assistant and advisor to the Secretary of Defense for all matters relating to the DOD Acquisition System; research and development; advanced technology; test and evaluation; production; logistics; military construction; procurement; economic security; and atomic energy. (DOD Directive 5134.1)

viability. Includes financial trends (profitability, capital investment, debt/equity ratio), mergers and acquisitions (consolidation, effect on overhead), and business base/mix

(civilian/military). (Air Force Industrial Base Assessment of the Aircraft Sector, December 1993, iv)

weapons of mass destruction. Nuclear, biological, and chemical weapons, along with their associated delivery systems, which pose a major threat to America's security and that of America's allies and other friendly nations. A key part of the U.S.'s national security strategy is to seek to stem the proliferation of such weapons and to develop an effective capability to deal with these threats. (*A National Security Strategy of Engagement and Enlargement*, February 1996, 19)

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